RECENT LITERATURE.

Heliotropic Animals.[1]—In connection with the work of Prof. E. B. Wilson upon the heliotropism of Hydra, (AMERICAN NATURALIST, May, 1891,) a brief review of the present paper of Dr. Loeb and some notice of other contributions to the same subject by the same author may not be without interest as pointing out the wide extension of such phenomena amongst animals and their identity with those commonly observed amongst plants.

The author's thesis is that experiments demonstrate a complete agreement between the movements that animals perform under the influence of light and those that have been demonstrated in plants.

Following Sachs the heliotropic phenomena of plants are briefly reviewed as follows:

Stems and roots which bend to or from the source of light until they take the *direction* of the light, are said to be positively or negatively heliotröpic. That this bending is not simply a process of greater growth on the more shaded side is shown by the fact that negatively as well as positively heliotropic plants grow more in the dark.

That the direction of the light is the determining movement is seen in the actual locomotion of many spores to or from the light.

The more highly refrangible rays, blue and violet, are the active ones in producing heliotropic movements.

Movements within a single cell result in the arrangement of chlorophyll bodies with reference to the direction of the incident light and as all plants are to be regarded as a continuously connected set of cells, or as one protoplasmic mass, the true explanation of heliotropic movements may invoke a movement of negative protoplasm away from and of positive protoplasm towards the light.

In plants, then, light produces an orientation dependent upon its direction and upon its character, wave length, etc., and continues to act a stimulus when of constant intensity.

A brief survey of the previous work upon heliotropism in animals serves to point out the insignificance of the results achieved.

Réaumur, 1748, and Trembley, 1791, made direct observations upon the effect of light upon moths and Hydra, but no extensive examination of the subject was attempted. Later Bert, 1869, Lubbock, 1883, and Graber, 1884, made extensive researches into the action of colored

[1]Dr. J. Loeb: Der Heliotropismus der Thiere. Würzburg, 1890.

light and light of varying intensity, but arrived at results that are to be objected to as too strongly implying the conscious action rather than the mechanical reaction of the animal when effected by light. Their anthropomorphic nomenclature, use of terms implying a preference for or love of one form of light and the method of determining this preference by taking the majority vote of the animals experimented upon, stands in striking contrast to the work of Stahl, 1880, and Engelmann upon Infusoria, for here we find the movements of orientation of the animal ascribed to the directive influence of the light, not to the animal's choice.

Dr. Loeb's experiments are conducted with the greatest simplicity of apparatus and the results are at once evident, yet it is to be borne in mind that animals may not exhibit heliotropism except at certain stages of their existence and even then the reaction to light may be neutralized or modified by the co-existence of other modes of stimulation. Thus insects respond, it seems, to peculiar contact stimuli in such manner as to place their bodies with reference to adjoining surfaces; some for instance, taking up positions upon projecting corners of a box, others only in the hollow angles.

The form of reaction to contact stimuli is distinguished as "Stereotropism" and together with geotropism will be later seen to play an important role in the resulting movements of animals when exposed to light.

The fifth section of the brochure deals with the experiments upon the caterpillars of *Porthesia chrysorrhœa* and serves as an introduction and detailed illustration of the methods and results subsequently described in other cases.

The experiments are as follows:

About 100 small caterpillars that have escaped from the nest in which they pass the Winter and which have not as yet taken food, are put into a test tube in a room at 12°–15° C.

When placed horizontally upon a table covered with black paper and with the axis of the tube at right angle to the window the caterpillars all crawl toward the window on the upper side of the tube, the head and ventral side directed towards the light; reaching the end of the tube they remain pointing towards the light.

As often as the tube is turned through 180° the caterpillars repeat the movement. If then the test tube is put parallel to the window the caterpillars scatter all along it but only upon the upper side. When in the first position the animals have collected at the window end of the tube they leave that end as soon as it is covered over by an

opaque object and crawl towards the lighted end, but as soon as they emerge from the obscured region they turn about with the head towards the window and remain thus at the boundary of obscured and illuminated parts of the tube—not scattering through the latter part.

By leaving a small area uncovered along the upper side of the obscured part of the tube when it is turned to the window, the caterpillars continue on into this region as if it were not covered at all, though passing towards the window from a more generally illuminated part of the tube into one only illuminated from a narrow line. They move along the upper side with ventral aspects towards the light.

All the experiments were conducted in diffuse daylight but succeed the same, though more rapidly, in direct sunlight. One other experiment upon the relation of movement to direction of light is this: the test tube with animals at one end, *a*, is put on the table with this end away from the window but in a strong beam of sunlight coming obliquely from the window to strike the test tube nearly at right angles. Now the animals are in the strong sunlight, but, directed as it seems, by the diffuse light coming from the other end of the tube, *b*, nearer the window, they all wander toward that end, *b*. Modifying this so that the end, *b*, is in the sunlight while the end, *a*, is away from the window and in diffuse light the animals still go toward the window though now leaving the lesser illumination for the more intense one.

To determine the action of light of various refrangibility the tube is covered by colored glass. Thus if blue glass cover the entire tube the animals act as if white light were used, but under red glass they react very slowly indeed. The same results are obtained with colored solutions instead of glass.

Covering one end of the tube, (either end) with blue glass produces no visible result other than that observed when white light was present all along the tube, but if red glass be used the animals move just as if the red region were the obscured, not illuminated region, of the first experiments. When the window end is covered by red and the room end by blue, the animals collect at the boundary between the two when the tube is perpendicular to the window, but when parallel to the window they distribute themselves all along the blue region.

It is thus the more strongly refrangible rays which are effective, the less refrangible rays having little influence.

A certain intensity of light is necessary in these experiments since in the evening the light gradually ceases to produce movements and artificial light may be intense enough to act like sunlight. Moreover

of two unequal lights the more intense is followed by caterpillars. In all the experiments the stimulus continues as long as the light remains unchanged: the caterpillars remain at the end of the tube though the other end may be open.

Other stimuli that might vitiate the result ascribed to light are to be mentioned under the titles of negative geotropism, contact and temperature. The first phenomena are those seen when the animals creep up a vertical surface, but this is overcome by the action of light as shown by illuminating the tube from below through a narrow slit in an opaque covering, then the animals overcome the negative geotropic tendency and move down towards the light.

The effects of contact stimuli are seen in the tendency of the caterpillars to collect on the convex edges and corners of solids—a tendency that controls their position upon the buds of trees as well as on the objects offered them in the laboratory.

A source of warmth is unlike a source of light in that the caterpillars move away from it: this is made evident from experiments upon the animals in opaque boxes when brought near a closed stove. The movements are, however, not in the line of direction of the heat rays.

These experiments in *Porthesia* have been repeated upon nearly 100 species of insects but with the same results, so that they will serve as type of the reaction of a positively heliotropic animal.

Certain special cases of interest remain to be discussed: first the old problem of the moth and the candle.

When *Sphinx euphorbiæ* or other nocturnal moths are kept in a glass box they fly towards the window side at dusk, or in the daytime if disturbed. When an artificial light and a window are at opposite sides of the room the moth goes to one or the other according to the intensity.

Here also it is shown that it is the blue and not red light which directs the flight. It seems that these nocturnal moths have periods of sleep followed by periods of greater sensitiveness to light—being sensitive in the night. This rhythm is moreover not easily disturbed for when kept several days in a dark box the moths still continue to be restless in the evening. During the period that they are heliotropic they agree with the *Porthesia* caterpillars in all respects.

Plant lice in the winged state exhibit strong positive heliotropic movements and are also negatively geotropic and forced to move away from heat just as are the larvæ of *Porthesia.*

The young however offer unexplained phenomena, in not reacting to light but having definite positions upon the stem and under sides of the leaves of plants that do not appear due to any of the above causes.

Ants however are not heliotropic in the winged state until the period of sexual excitement, when they swarm out for the nuptial flight. Such ants gave the same results in the laboratory experiments as did the caterpillars under the same circumstances.

The two sexes differ, however, in that the males continue to go towards the light when its intensity has become too slight to affect the female. The others seem not to be heliotropic at all, from the author's observations at least.

The ninth chapter is devoted to the phenomena exhibited by flies. The larvæ of *Musca vomitoria* were experimented upon, either in test tubes or directly upon the table, and yielded the same result regarding the directive influence of light, white and colored, with the important exception that the animals move away from and along the direction of the light, being in fact *negatively* heliotropic.

That this is true of the youngest larvæ at time of hatching is demonstrated by allowing eggs to hatch out upon plates blackened with soot: the young then leave traces of their lines of progress and these are away from the light. If two windows at right angles supply light, the direction of march is in the diagonal between the two lines of stimulation. When, however, the eggs hatch in darkness, the young crawl in all directions. Certain complications, however, arise in the course of young larvæ as they seem to have a peculiar tendency to arrange themselves with the ventral side turned toward the light, provided this is strong sunlight. Heat appears to exercise no definite directive influence, though the presence of food causes them to move towards it and there is also a strong contact stimulus evinced in the tendency the larvæ exhibit to crawl under foreign bodies—passing thus under plates of transparent glass where negative heliotropism cannot be cited as the cause of the movement.

Though the larvæ are thus negatively heliotropic the adult fly is positively heliotropic as can be seen by repeating the experiment applied to the plant lice. Here however the problem is often made more complex by the numerous other stimuli which may act upon the fly and more or less nullify the results of heliotropism.

Negative heliotropism is shown also in the larvæ of two beetles, *Tenebrio molitor* and *Melolontha vulgaris*, combined in the first case with the peculiar contact sensitiveness, stereotropism, that leads the larvæ to collect in the concave angles of a dark box.

Though Dr. Loeb's experiments have been for the most part made upon insects, yet he states that he has been able to demonstrate heliotropism identical with that of plants in frogs, white mice, *Gammarus locusta, Cuma rathkii,* slugs, planarians, earthworms, leeches, and other worms.

Apparently the experiments of Romanes upon echinoderms are entirely unknown to him.

In this connection two other contributions to the subject of animal heliotropism, both by Dr. Loeb, may be reviewed as extending the observed facts over a wider field.

Groom and Loeb[1] found by direct experiment upon the larvæ, nauplius, of a barnacle, that these animals swim towards or away from the light, following the direction of the light and not going towards the more intense light. Moreover, here as elsewhere, it is the more refrangible rays which are most potent.

The heliotropic movements are, however, not always positive or negative but are interchangeable in any one individual, so that after the larvae have been in the dark some time they are all positively heliotropic, but when exposed to the light and moving towards it for some time they become, some sooner than others, negatively heliotropic and swim away from the light, etc.

This alternation of effect in the action of light is then applied by the authors to the explanation of some of the diurnal changes in the position of pelagic organisms, their wandering to and from the surface of the sea.

In another paper[2] Loeb shows by experiment upon the large annelid *Spirographis spallanzanii* that here also the annelid turns towards the source of light, placing its body so that the axis of its somewhat umbrella shaped expansion of radiating branchial plumes coincides with the direction of light. Now as the animal is a sedentary annelid living in a stout leathery tube from which only the branchial and anterior end protrude, this tendency to point to the light is resisted by the elasticity of the tube.

The tube however is found to bend also, after some time, so as to incline one way or another according to the direction of light, and then remain permanently bent for months, in fact when the animal is removed the tube is still bent.

[1]Groom and Loeb: Der Heliotropismus der Larven von Balanus perforatus. Biolog. Centralblatt, X, pp. 160–177, 1890.

[2]Dr. J. Loeb: Weitere Untersuchungen über den Heliotropismus der Thiere. Bonn, 1890.

As a direct bending of the tube by mechanical force does not result in this permanent change of form the author seeks to explain the observed result by the suggestion that the animal, bending to one side, reconstructs or adds to the walls of the tube on that side and so forces it to maintain its new position.

Again in a Serpula which lives in an inelastic calcareous tube, experiment shows that by changing the direction of light the tube becomes also changed in its direction. Here, however, the process is a very slow one and results from the growth of the newly formed part of the tube in the direction in which the worm turns its branchiæ and head under the influence of light; the tube once formed does not bend.

The dependence of the arrangement of animal structures upon the direction of light is shown again in the case of a certain sertularian hydroid. When pieces of the stem are inserted upsidedown in sand the old lower end, now exposed to the light, sends out both new stems and new roots. The new stems, as they grow, take the direction of the light rays and so do the new roots, but the former grow towards the light the latter directly away from it; are then positively and negatively heliotropic respectively. Adventitious roots coming out from the inverted stem show again this same negative heliotropism.

In the light of these and other experiments upon the direct response of animals to stimulation by light, gravitation, contact, etc., the author here protests against the introduction of "instinct" and "will" in the explanation of such phenomena, relegating such expressions to the same category as "vital force."

To return to the main paper.

Another extension of heliotropic phenomena is made in the case of the movement of the pigmental processes of the outer cell-layer of the retina in man under the action of light. In this part of the subject the author has no new observations to record, though his explanation of the movements of orientations of eye and head as due to the above heliotropism is sufficiently novel. The twelfth chapter concludes this contribution to heliotropism. Here we find some new facts brought together with some of those observed upon insects to show that the movements of an animal when acted upon light depend upon its morphological structure. Thus in a bilaterally symmetrical animal the oral end is found to be more irritable than the aboral end, the dorsal and the ventral sides not equally irritable, while symmetrical points right and left of the median plane are equally irritable. Hence arises the tendency to move directly towards or away from the light

with the median plane in the line of light, and the peculiar tendency to place the ventral or dorsal side towards the light in some cases.

In an appendix certain interesting experiments upon geotropism in insects are communicated in addition to those mentioned in the part treating of heliotropism. That caterpillars and beetles, (Coccinella) rapidly ascend vertical sides of boxes and remain at rest at the top is ascribed to a negative geotropism; while the various positions taken up by cockroaches, butterflies, spiders, etc., when at rest is likewise an orientation with reference to gravitation, direct or indirect.

Most suggestive experiments in extension of this view in which it appears that insects in a centrifugal machine perform some of the compensating movements ascribed to the function of the semicircular canals in vertebrates can be only mentioned in passing as they lead too far from the main thesis. That the geotropism is not confined to insects is well shown by Loeb[1] in the case of certain sea cucumbers (*Cucumaria cucumis*) which ascend to the top of an aquarium even when the apparatus is so devised that there is no question of greater air supply etc., at the top.—E. A. ANDREWS, Feb. 12, 1892.

The Homologies of the Cranial Arches of the Reptilia.—The following paragraphs contain an abstract of a paper read before the U. S. National Academy of Science under the above title on April 19th, and published in the Transactions of the American Philosophical Society in May, 1892.

The paper recorded an analysis of the cranial characters of the genera of Reptilia discovered in Permian beds in North America by myself. Those especially studied are Pariotichus, Pantylus and Chilonyx, which belong to the Cotylosauria (Cope; Pariasauria Seeley); and Edaphosaurus, Clepsydrops and Naosaurus, members of the Pelycosauria (perhaps equal the Theriodonta of Owen); and Diopeus g. n., founded on *Clepsydrops leptocephalus* Cope. The Cotylosauria have the temporal fossæ overroofed, so that the skull has the general character of that of the Stegocephalous Batrachia, with which it also agrees in its segmentation, an agreement especially well marked in Chilonyx.

The hypothesis of Baur was tested in its application to the origin of the bars of the Reptilian skull. This hypothesis supposes that the bars have been derived from the Cotylosaurian roofed skull by perforation, a kind of natural trephining; the position of which has determined the position and constitution of the bars or remaining portions

[1]J. Loeb: Ueber Geotropismus dei Thiere. Arch. f. d. ges. Phys. xlix., 1891.